North Carolina
Department of
Transportation

# Chapter 7 Hydrology

January 2022

| Revisions Sheet | | | |
|---|---|---|---|
| **Page** | **Old Section** | **New Section** | **Description** |
| - | - | - | • Entire Chapter revised to new format and minor grammatical changes made throughout<br>• All references and links have been updated throughout Chapter |
| 1 | 7.1 | 7.1 | Last sentence revised. |
| 1 | 7.2 | 7.2 | 1st sentence – Removed "relatively new" from USGS StreamStats, Removed reference to Appendix E and Updated links |
| 1 | 7.2.1 | 7.2.1 | Revised link |
| 2 | 7.2.3.2 | 7.2.3.2 | Last sentence added |
| 3 | 7.2.4 | 7.2.4 | Link added |
| 3 | 7.3 | 7.3 | • Revised 3rd sentence<br>• Last sentence added |
| 3 | - | 7.3.1 | Added new section – Level of Service Determination |
| 4 | 7.4 | 7.4 | Removed 3rd sentence |
| 5 | 7.4 | 7.4 | Table 2 – Revised Rational Method up to 100 acres; Removed "(for routing" from NRCS Method; Added asterisk and footnote for NCDOT Hwy Hydrologic Charts |
| 7 | 7.4.2.3 | 7.4.2.3 | Entire section revised |
| 7 | 7.4.3 | 7.4.3 | Last sentence – Revised upper limit to 100 acres |
| 8 | 7.4.3.2 | 7.4.3.2 | Removed 3rd paragraph |
| 8 | 7.4.4 | 7.4.4 | Entire section revised |
| 10 | - | 7.6 | Added new section - References |
| 12 | - | 7.7 | Added new section – Additional Documentation |
| 12-17 | Appendix C | 7.7 | Added NCDOT Charts |

# Table of Contents: Chapter 7, Hydrology

# 7.1 Introduction

The hydrologic analysis phase involves determining the discharge rates and volumes of runoff that drainage facilities are required to convey. This chapter discusses the acceptable hydrologic methods for highway drainage studies and applicable criteria for their use. When the project site involves a FEMA-regulated stream, discharge methods and values provided in the effective published Flood Insurance Study (FIS) report should be used for determining compliance with National Flood Insurance Program (NFIP) regulations (FEMA 2016). This may result in the need for additional hydraulic modeling to meet NCDOT design criteria, so there may be both a model for NFIP compliance as well as a design model for the NCDOT project. The results from any hydrological procedure should be calibrated with historical site information. The Design Engineer should also consider land use changes over the life of a project and non-stationarity in future climate projections, and include these effects when estimating design discharges. (See Chapter 6 for more guidance regarding project resilience.)

# 7.2 Drainage Area Determination

There are a variety of sources for obtaining drainage area data, including:

- USGS topographic contour maps
- published lists of drainage areas from study reports (such as FEMA Flood Insurance Studies and USGS water data reports)
- archived NCDOT Bridge and Culvert Survey and Hydraulic Design Reports (BSR, CSR)
- digital elevation data (such as Light Detection and Ranging, or LiDAR, data)
- USGS StreamStats web-based GIS application for North Carolina, which utilizes Digital Elevation Models (DEMs) based on LiDAR data and a combination of local resolution stream data and National Hydrography Datasets (NHD) for automated computation of drainage areas and other basin characteristics.

Drainage areas should be verified during project field review. The Design Engineer is responsible for verifying the accuracy of the drainage area, regardless of the method used to obtain it.

## 7.2.1 USGS StreamStats

StreamStats is a web-based GIS application that was released by USGS in 2012. It allows users to easily obtain streamflow statistics, basin characteristics, etc., for USGS gage data collection stations and for user-selected ungaged locations. The application will delineate the drainage area at user-selected stream locations. The website includes comprehensive instructions and associated help files, including *Getting Started* and *Quick Tour* links. Users should review this information before attempting to use the application.

## 7.2.2 USGS Quadrangle Maps

USGS topographic mapping is available through the *National Map Viewer* website http://nationalmap.gov. Additionally, a GIS web map service (WMS) called USA_Topo_Maps provides a base map of national coverage of USGS topographic contour mapping.

## 7.2.3 Digital Elevation Data

Several sources of digital elevation data are available. MicroStation Triangular Irregular Network (TIN) files provide the primary and most current, accurate, and readily available data file, and is supplied by NCDOT Location and Surveys and Photogrammetry Units for the specific project area. Since this coverage is often inadequate for hydrologic studies, it may need to be supplemented with other digital elevation data sources, such as LiDAR coverage or USGS Digital Elevation Models. Further details on each of these are discussed below.

### 7.2.3.1 MicroStation TIN Files

NCDOT's Location and Surveys Unit and Photogrammetry Unit collaborate to produce the final survey files for NCDOT projects, including planimetric mapping, Digital Terrain Models (DTMs), and associated TIN files. The DTM file is first generated from processing the raw survey data. The DTM file is then used to generate a TIN file to represent the existing ground surface. The original TIN files provided for a project do not always provide adequate geographical coverage for hydrologic analyses (e.g., offsite drainage), so supplemental digital elevation data may be used to generate additional TIN file coverage that can be merged with the original TIN.

### 7.2.3.2 LiDAR Data

One supplemental source of digital elevation data available in North Carolina is the statewide Light Detection and Ranging (LiDAR) coverage that was developed for the NC Floodplain Mapping Program (FMP). The entire State has been mapped using LiDAR techniques to collect digital elevation data. These data and corresponding metadata are available for download and can be accessed from FMP's website (http://www.ncfloodmaps.com). Additional information regarding availability and quality of LiDAR data can be found on NCDOT Photogrammetry Unit's website.

### 7.2.3.3 USGS Digital Elevation Models and Local Government Topographic Data

Digital Elevation Model (DEM) data are available from the USGS National Elevation Dataset (NED). Procedures on how these data can be downloaded are provided on the *National Map Viewer* website (see 7.2.2). These DEMs may prove most useful for areas in bordering states. Within the state, NC FMP's LiDAR coverage will likely be more current, higher resolution, and accurate than that available from the NED. Additionally, larg e municipalities and some counties have developed topographic and elevation data which may be publicly available for use in drainage area determination.

### 7.2.4 Archived NCDOT Bridge and Culvert Survey and Hydraulic Design Reports

The Hydraulics Unit archives thousands of bridge and culvert design reports, in both hard copy and PDF formats. (https://connect.ncdot.gov/sites/hydro/Reservoir/Pages/default.aspx)

These reports provide valuable hydrologic and hydraulic information, such as drainage area size, discharge rates and associated computed water surface elevations, methods used for computations, flood history records, etc. The Design Engineer should verify the information on the report before relying on it, since the information provided on these reports is only as accurate as the methods and technology available as of the date of the report.

### 7.2.5 FEMA Flood Insurance Studies

FEMA Flood Insurance Study (FIS) Reports' Summary of Discharges Tables are a good source for drainage areas and associated computed discharges for the FEMA hydraulic models. (See Section 7.4.1 for more information.)

## 7.3 Peak Discharge Design Frequency

Design frequency for NCDOT drainage structures is determined based on the roadway classification, traffic volume, level of service, flooding potential to properties, maintenance cost, etc. A summary of design frequencies that are typically used for NCDOT roadway drainage facilities is provided in Table 1. Consideration for site-specific conditions, such as upstream or downstream potential property impacts, existing level of service provided, length of time a temporary detour will be in place, etc. may warrant exceptions to these and should be discussed during the planning phase and agreed upon during the pre-design review. See Chapter 12, Section 12.3 for the criteria to specify the design frequency for temporary pipes or diversion channels for culvert construction sequencing.

### 7.3.1 Level of Service Determination

The hydraulic level of service is a performance standard for NCDOT highways. It is based on defined design storm to subsequently set minimum hydraulic design standards for the project. Table 1 provides the standard minimum design frequencies for various hydraulic elements based upon roadway classification.

**Table 1. Design Frequency**

| Roadway Classification | FREQUENCY (years) | | | |
|---|---|---|---|---|
| | Bridges, Culverts and Cross Pipes | Storm Drain System | | Ditches |
| | | On Grade | At Sags (without relief) | |
| Major Arterials (e.g., Interstates, US, NC Routes) | 50 * | 10 | 50 | 10 |
| Minor Arterials, Collectors, and Local Roads | 25 | 10 | 25 | 10 |
| Temporary / Detours | 10 | - | - | 10 |

*While it is not practicable to design an entire highway system so that damage or closure due to extreme flood events will never occur, it is possible to reduce the risk of occurrence by implementing an increased level of service where warranted. For example, it would be considered reasonable and prudent that higher hydraulic performance standards for the Strategic Transportation Corridor network, major arterials, evacuation routes, and other important roadways should be carefully considered during planning and design to include, among other things, risk to commerce, accessibility, and evacuation due to road closure caused by inundation, including non-stationarity in future climate models.

Some roads may warrant a lesser hydraulic design frequency. In these instances, discussion and analysis of inundation probability and duration that are less than the design storms listed in Table 1 should be documented.  The documentation should include criticality of the roadway and access concerns.

See Chapter 3 for more information regarding hydraulic planning-level studies.

# 7.4 Peak Discharge Estimates

The Design Engineer should select from several acceptable peak discharge methods, depending upon the site's watershed characteristics. Table 2 lists peak discharge methods which are acceptable for NCDOT hydrologic studies. It is the Hydraulic Engineer's responsibility to apply sound engineering judgment and to provide documented justification of methods used. Reported discharges should be expressed to two significant figures for 0.1 cfs to 10,000 cfs, and if higher, to three significant figures (examples: round 135.22 to 140; round 13,522 to 13,500), unless specifying discharges cited identically from a published FEMA Flood Insurance Study report.

**Table 2. Peak Discharge Method Selection**

| Hydrologic Methods | FIS (for NFIP compliance) | USGS Methods | Rational Method (up to 100 ac) | NRCS Method | NCDOT Hwy. Hydrologic Charts* |
|---|---|---|---|---|---|
| Bridges | X | X | | X | |
| Culverts | X | X | | X | |
| Storm Drain Systems | | | X | X | X |
| Cross Pipes (≤ 72 in. dia.) | X | X | X | X | X |
| Gutter Spread | | | X | | |
| Ditches and Channels | X | X | X | | X |
| BMP Devices | | | X | X | |
| Natural Stream Design | X | X | X | X | |
| Storage Facilities | | | | X | |
| Floodplain Impacts | X | X | | X | |

*Use NCDOT Charts only in Region 2 (mountain regions)

## 7.4.1 FEMA Flood Insurance Study

If a project study site is on a FEMA-regulated stream that is included in a published effective FEMA FIS, the discharges specified in the FIS Summary of Discharges table should be used in the hydraulic model to demonstrate FEMA regulatory compliance. Streams studied by detailed methods will typically list computed discharges for the 10- , 50 -, 100-, and 500-year recurrence intervals. Streams studied by limited detailed methods will only list the 100-year discharge.

View and download copies of effective FIS reports from NC Floodplain Mapping Program's (NC FMP) website (http://www.ncfloodmaps.com).

## 7.4.2 USGS Stream Gage Analysis

Precedence should be given to analysis of the published stream gage data records when a USGS gage exists at or near the study site. Published North Carolina flood frequency statistics from continuous record USGS gages are available from the Flood-Frequency Statistics USGS Gaged Sites web link (http://nc.water.usgs.gov/flood/floodstats/gaged/index.html)

### 7.4.2.1 Peak Discharge Estimation at Gaged Site

The above USGS website provides three types of statistical peak discharge estimates.

- The first is computed by fitting the recorded annual regulated peak flows to the log-Pearson Type III distribution using a localized computed sample skew.
- The second is computed from the appropriate regionalized regression equation developed for the hydrologic area of the gage station location.
- The third combines the results of the first two into a weighted estimate for that gage station. This is presumably the most accurate and reliable estimate.

Details on how these estimates are computed are discussed in USGS report SIR 2009-5158 (USGS. J.C. Weaver, T.D. Feaster, A.J. Gotvald (authors) 2009 (rev. 2015)). This report also discusses how flood-frequency peak discharge estimates at gaged sites can be adjusted (by transposition) to ungaged sites, as summarized in the following guidance.

### 7.4.2.2 Peak Discharge Estimation at Ungaged Site near Gaged Site

If the study site is not at the location of a reference stream gage station on the same stream, and the drainage area at the study location is within fifty percent of that of the reference gage station, it is acceptable to adjust (or transposition) the discharge from the gage station to compute discharge estimates at the study location. The recommended method for peak discharge transposition is detailed in USGS report SIR 2009-5158 (USGS. J.C. Weaver, T.D. Feaster, A.J. Gotvald (authors) 2009 (rev. 2015)). This method is not recommended if the difference in drainage areas between the two locations is greater than fifty percent. If the ungaged site is located between two gaged stati ons on the same stream, two peak discharge estimates can be made using the above procedure. Hydrologic judgment can be applied to determine which is the more appropriate of the two.

#### 7.4.2.3 Peak Discharge Estimation at Ungaged Site

In 2012, USGS launched the North Carolina StreamStats application website. In addition to the recommended use of this application for its automated drainage area delineation capabilities (see 7.2.1), this application is also recommended for use in computing discharges from USGS regression equations at ungaged sites. The Design Engineer is responsible for reviewing the validity of equations and variables, and for being familiar with the limitations of any equations used by StreamStats. The Design Engineer should also note the IA percent used in calculating discharges and adjust as needed to account for changes in IA or for future development. SIR 2014-5030 (USGS. T.D. Feaster, A.J. Gotvald, and J.C. Weaver (authors) 2014) should be used whenever applicable. For rural basins outside of applicability of 2014-5030, the rural regional regression equations presented in SIR 2009-5158 (USGS. J.C. Weaver, T.D. Feaster, A.J. Gotvald (authors) 2009 (rev. 2015)).

For urban basins outside of applicability of SIR 2014-5030, such as Region 2, use WRI 96-4084 (USGS. J.C. Robbins, B.F. Pope (authors) 1996), or USGS Fact Sheet 007-00 (USGS. R.R. Mason, Jr., L.A. Fuste, J.N. King, and W.O. Thomas, Jr. (authors) 2002), as applicable. There may still be some situations where the basin characteristics are outside of the limits of all the USGS publications and the Design Engineer should use judgement in determining the most applicable method. If the StreamStats website is unavailable, refer to guidance in the referenced reports.

### 7.4.3 Rational Method

The Rational Method estimates the peak discharge (Q) in cubic feet per second (cfs) as a function of drainage area (A) in acres, mean rainfall intensity (I) in inches per hour (for a duration equal to the time of concentration, $t_c$), and a dimensionless runoff coefficient (C). The Rational Formula is Q = CIA. NRCS methods, as presented in TR-55 (NRCS 1986) and TR-20 (NRCS 2015) should be used for calculating $t_c$. Minimum value for $t_c$ should be 10 minutes. An upper limit of 100 acres drainage area is recommended for applicability of this method.

#### 7.4.3.1 Rational Runoff Coefficient

The value of the runoff coefficient (C) increases with the imperviousness of the surface cover. Table 3 provides commonly used values for various surface types (FHWA. R.H. McCuen, P.A. Johnson, R.M. Ragan (authors) 2002). The higher values in the ranges shown should be used when the terrain slope is steep. Less permeable soils warrant higher range C values. Likewise, areas such as grassed medians and berms behind curb and gutter may also warrant higher C value because of reduced permeability due to soil compaction performed during construction.

**Table 3. Typical Rational Runoff Coefficients**

| Type of Surface | C |
|---|---|
| Pavement | 0.7 - 0.9 |
| Gravel surfaces | 0.4 - 0.6 |
| Industrial areas | 0.5 - 0.9 |
| Residential (Single-family) | 0.3 - 0.5 |
| Residential (Apartments, etc.) | 0.5 - 0.7 |
| Grassed, steep slopes | 0.3 - 0.4 |
| Grassed, flat slopes | 0.2 - 0.3 |
| Woods / Forest | 0.1 - 0.2 |

#### 7.4.3.2 Rainfall Intensity

Obtain rainfall intensity (I) data from the NOAA Atlas 14 published report (NOAA. G.M. Bonnin, D. Martin, B. Lin, T. Parzbok, M. Yetka, D. Riley (authors) 2006) and corresponding Precipitation Frequency Data Server (PFDS) website, where “I” values are tabulated for a range of durations and storm event frequencies at user-selected locations. In the PFDS table, the duration which is closest to the computed time of concentration ($t_c$) value will be used to obtain the corresponding “I” value to use in the Rational Formula. Use a minimum of ten minutes.

Access the PFDS: https://hdsc.nws.noaa.gov/hdsc/pfds/

Intensity values in GEOPAK Drainage (Bentley Systems, Inc. 2010) are hard coded into the Drainage Library and may not exactly match the NOAA Atlas 14 values for a given location but should be relatively close. For routine storm drain system design, use the intensity values generated within GEOPAK Drainage.

### 7.4.4 NCDOT Highway Hydrologic Charts

The previous 2016 version of the Guidelines included the NCDOT Highway Hydrologic Charts, corrected and digitally reproduced from the 1973 State Highway Commission charts, which were provided in Appendix C of that version of Guidelines. They formerly were primarily used for sizing of small pipes. Due to more state-of-the-art hydrologic methods their usage is becoming obsolete, but the charts may still be used for small mountainous watersheds (Region 2) on a case-by-case basis. The charts have been provided in Section 7.7 for reference.

### 7.4.5 NRCS Methods – Storage Routing

Natural Resources Conservation Service (NRCS, formerly Soil Conservation Service) methods, presented in TR-55 (NRCS 1986) and TR-20 (NRCS 2015), are recommended for hydrographic storage routing. The TR-55 manual presents simplified hydrologic procedures for estimating flood hydrographs and peak discharges in small watersheds. The model begins with a rainfall uniformly imposed on the watershed over a specified time. Mass rainfall is then converted to mass runoff by using a runoff Curve Number (CN) which is based on soil type, land cover, impervious area, surface storage, infiltration rate, etc. Runoff is then converted to a hydrograph to develop peak discharges applying hydrograph routing procedures, runoff travel time, etc. TR-20 provides computer-aided hydrologic analyses for estimating flood hydrograph peak discharges in both small and large watersheds. For current soils data, visit the NRCS Web Soil Survey website:

(http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm)

Public domain software programs available from the Army Corps of Engineers Hydraulic Engineering Center (HEC) or NRCS are acceptable to perform hydrograph calculations and routing. Other hydrograph methods supported by FHWA and AASHTO ( (AASHTO 2007), (AASHTO 2014), (FHWA. R.H. McCuen, P.A. Johnson, R.M. Ragan (authors) 2002)) may be used with approval of the State Hydraulics Engineer.

## 7.5 Accuracy of Hydrologic Estimates

The USGS scientists used various statistical methods to perform hydrologic analysis to develop regression equations for estimating peak discharges for both gaged and ungaged sites. It contemplates the complex geomorphic system of precipitation, evaporation, evapotranspiration, infiltration, overland flow, impoundments, channel flow, etc. The hydrologic analysis is not an exact science. The accuracy of the estimated discharges may vary significantly depending on location and other contributing factors. For example, the average standard error for the ten-year peak discharge in the Piedmont region is 25%; it is 73% for the 500-year peak discharge in the Sand Hills region (USGS. T.D. Feaster, A.J. Gotvald, and J.C. Weaver (authors) 2014).

It can be argued that some hydrologic methods are more accurate than others. Estimated discharges should be calibrated to locally observed or measured events. Methods should be applied within their limits of applicability and with understanding of the underlying assumptions and hydrologic principles supporting them. While detailed hydrologic analysis is not practicable and would be beyond the scope expected in normal NCDOT hydraulic engineering practice, the Design Engineer should calibrate the results from any hydrologic procedure to historical data. For bridge hydraulic analysis (see Chapter 8), these NCDOT *Guidelines* recommend that comparison be made to at least one historical occurrence.

# 7.6 References

AASHTO. 2014. *Drainage Manual.* Washington DC: Technical Committee on Hydrology and Hydraulics, Highway Subcommittee on Design, American Association of State Highway and Transportation Officials.

AASHTO. 2007. *Highway Drainage Guidelines, Fourth Edition.* Washington DC: American Association of State Highway and Transportation Officials.

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FHWA. R.H. McCuen, P.A. Johnson, R.M. Ragan (authors). 2002. "Highway Hydrology, Second Edition, Hydraulic Design Series Number 2 (HDS-2)." *Federal Highway Administration, U.S. Department of Transportation.* October. Accessed December 2021. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif02001.pdf.

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NRCS. 1986. "Technical Release TR-55 Urban Hydrology for Small Watersheds." *U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division.* Accessed December 2021. https://nationalstormwater.com/wp/wp-content/uploads/2020/07/Urban-Hydrology-for-Small-Watersheds-TR-55.pdf.

—. 2015. "WinTR-20, Version 3.20 - Computer Program for Project Formulation Hydrology." March. Accessed December 2021. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1042793.

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USGS. J.C. Robbins, B.F. Pope (authors). 1996. *Estimation of Flood-Frequency Characteristics of Small Urban Streams in North Carolina, Water-Resources*

*Investigations Report 96-4084.* Reston, VA: United States Geological Survey, United States Department of the Interior.

USGS. R.R. Mason, Jr., L.A. Fuste, J.N. King, and W.O. Thomas, Jr. (authors). 2002. *The national flood-frequency program—Methods for estimating flood magnitude and frequency in rural and urban areas of North Carolina, 2001: U.S. Geological Survey Fact Sheet 007–00.* Reston, VA: United States Geological Survey, United States Department of the Interior.

USGS. T.D. Feaster, A.J. Gotvald, and J.C. Weaver (authors). 2014. *Methods for estimating the magnitude and frequency of floods for urban and small, rural streams in Georgia, South Carolina, and North Carolina, 2011; Scientific Investigations Report 2014-5030, Version1.1.* Reston, VA: United States Geological Survey, United States Department of the Interior.

# 7.7 Additional Documentation

**NCDOT Hydrologic Charts**

(Revised and digitally reproduced from 1973 State Highway Commission charts)

List of Charts:

| Chart number | Description |
|---|---|
| C200.1 | Hydrologic Contour (HC) Map |
| C200.2 | Rural Runoff |
| C200.3 | Urban Runoff |
| C200.4 | Rural Drainage Area (DA) Shape Correction |
| C200.5 | Rural Drainage Area (DA) Land Cover Correction |

Procedure for rural watersheds:

1. Verify DA < 1 sq. mi.; otherwise, SHC charts not applicable.
2. Determine HC from C200.1 to nearest 0.5 interval. In highly channelized areas, particularly in coastal areas, a value of 1.0 above that shown in C200.1 should be used. Thus, it is unlikely that a value less than 4.0 would ever be used.
3. In C200.2, determine 50-yr discharge ($Q_{50}$) for the given HC and DA values. For other frequencies, apply the appropriate frequency factor listed. These values may need to be adjusted further for DA shape and land cover, as outlined in following steps 4 and 5.
4. Determine shape parameter W/L. From this and the DA, the shape correction factor can be determined in C200.4.
5. With the DA and percentage forest cover, use C200.5 to determine the land cover correction factor. Do not use this factor to reduce discharge unless future development in the watershed is not anticipated, such as in certain mountainous, wetland, or designated preservation areas.
6. Acceptable values for the multiple of shape and land cover correction factors are limited to the range of 0.7 to 1.5. Apply the adjustment factors to the discharge values determined from step 3.

Procedure for urban watersheds:

1. If DA < 20 acres, verify whether Rational Method would be more appropriate to use instead of the SHC charts. Also, if DA > 100 acres, C200.3 is not applicable. If uncertain whether watershed is urban, calculate discharges for both urban and rural conditions, then apply appropriate engineering judgment and document which results are deemed appropriate for study site.
2. Determine HC from C200.1.
3. Determine type and relative density of development to determine the appropriate development density adjustment factor.
    a. Residential – high type: lot sizes > 0.5 acres
    b. Average Development: small lots < 0.5 acres, or mixed residential / small business
    c. Large area – full business: DA >75 acres
    d. Small area – full business: DA < 75 acres
4. In C200.3, use HC and DA to obtain 10 yr. discharge ($Q_{10}$). Apply appropriate adjustment factor for other frequency events and development density adjustment from step 3.

10/13/2016

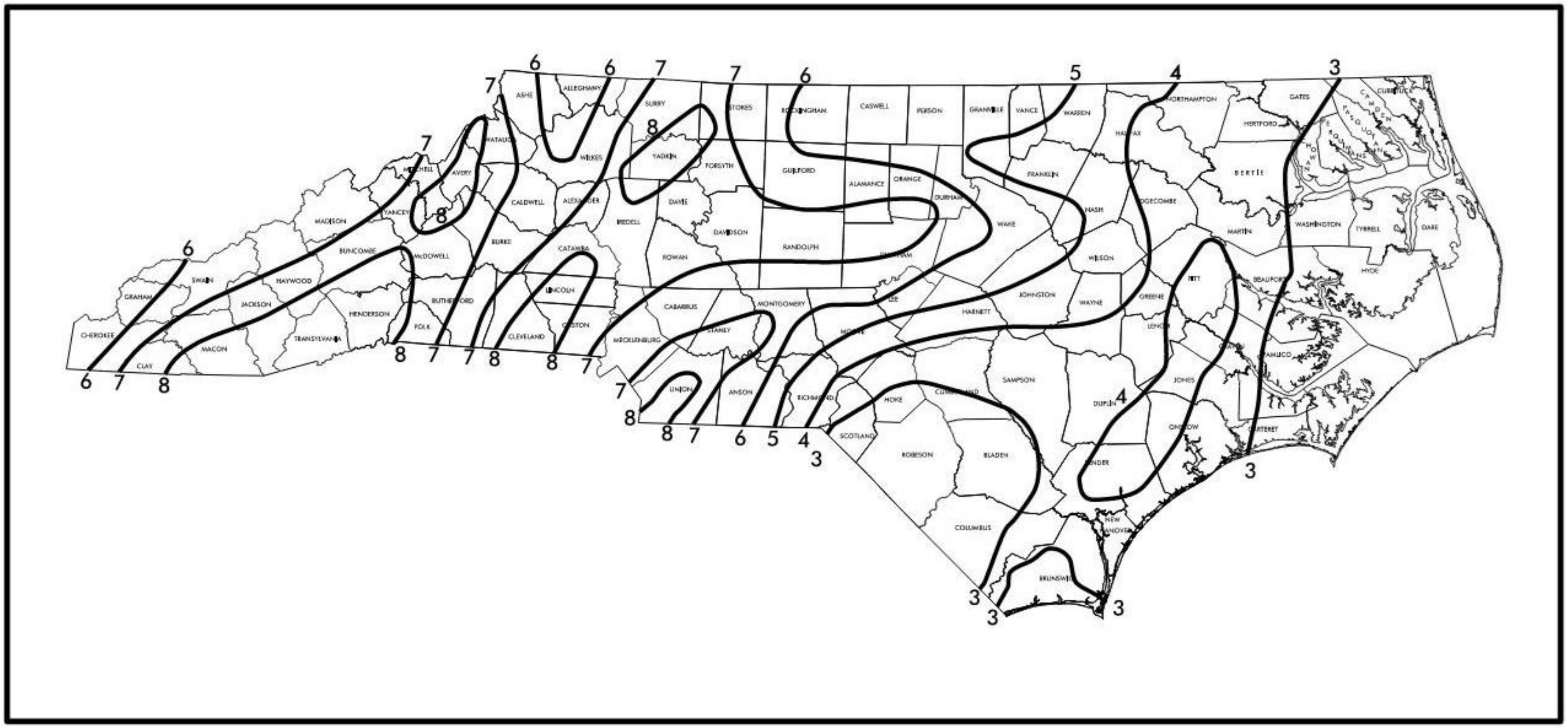
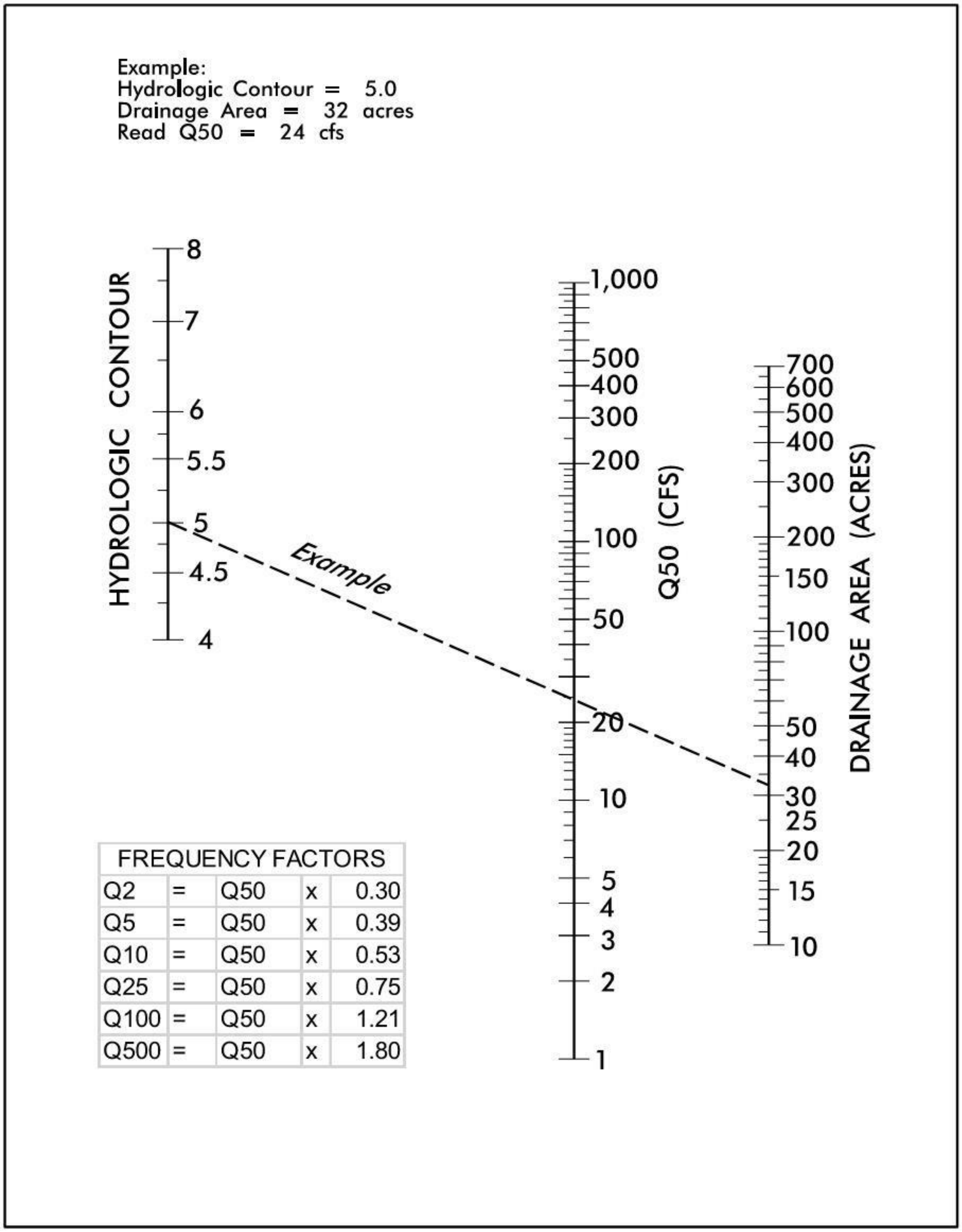


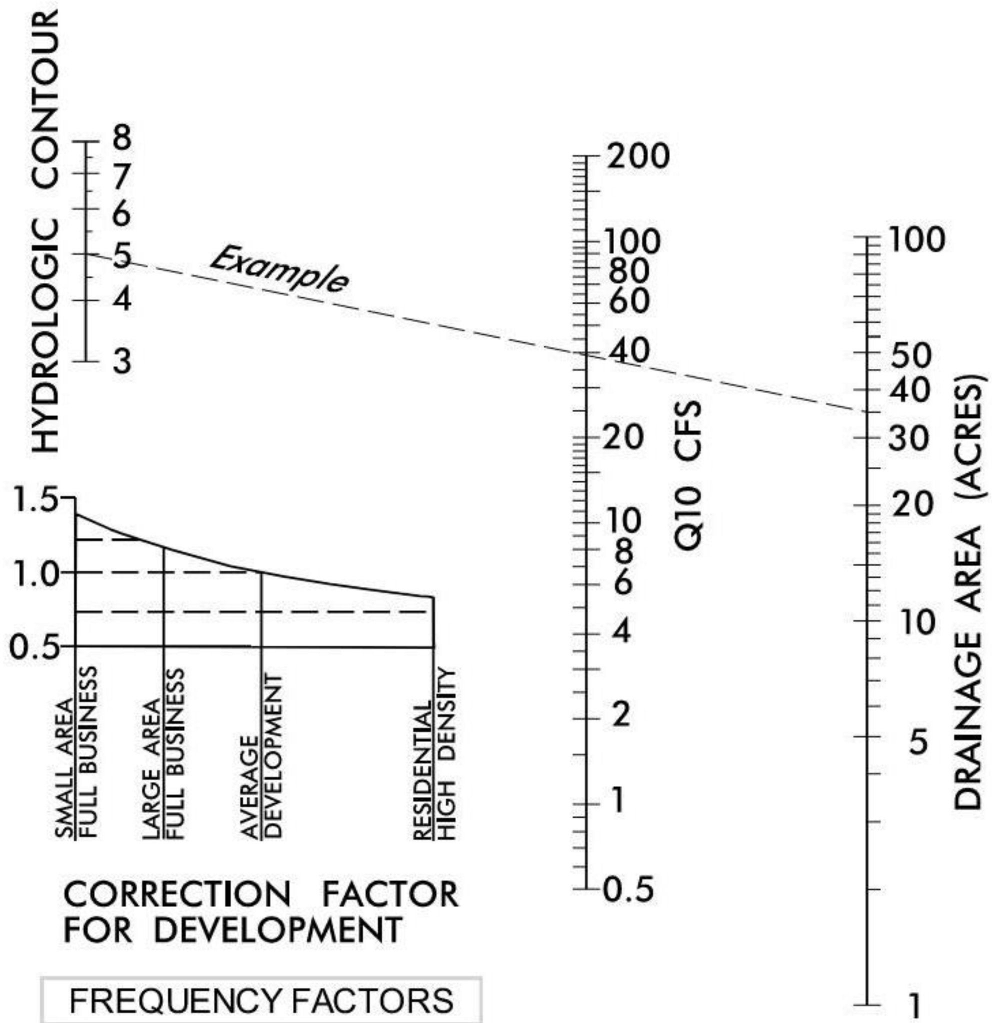
Chart C200.1 NC Hydrologic Contours




| FREQUENCY FACTORS | | | | |
|---|---|---|---|---|
| Q2 | = | Q50 | x | 0.30 |
| Q5 | = | Q50 | x | 0.39 |
| Q10 | = | Q50 | x | 0.53 |
| Q25 | = | Q50 | x | 0.75 |
| Q100 | = | Q50 | x | 1.21 |
| Q500 | = | Q50 | x | 1.80 |

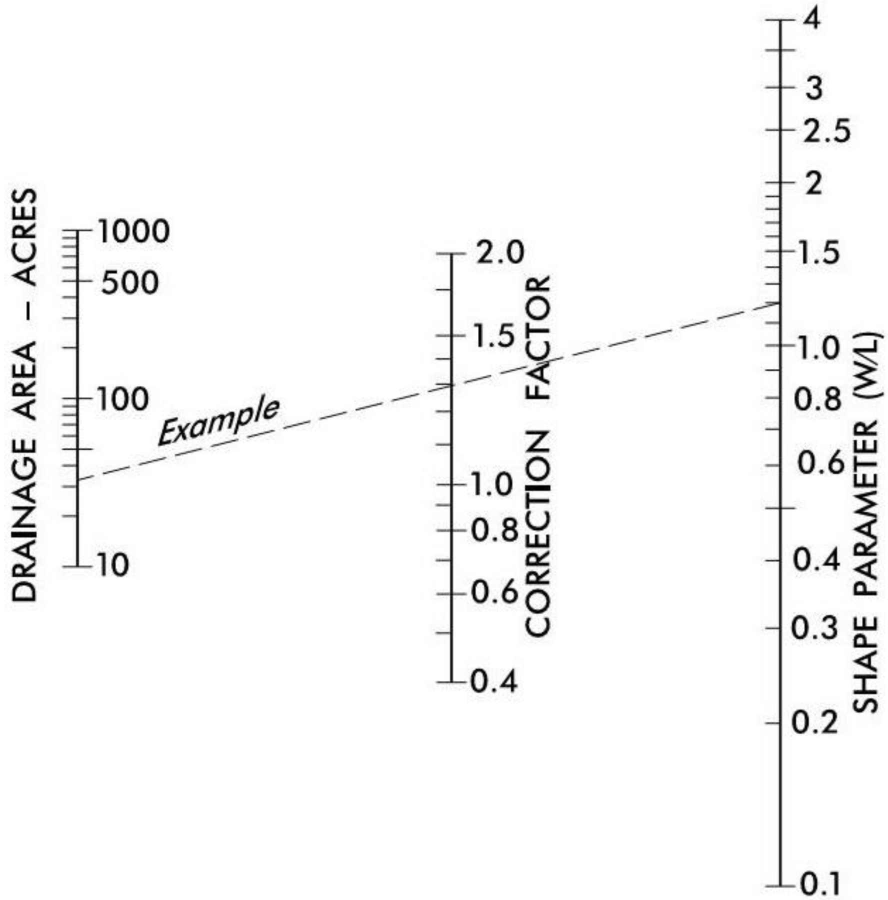
C200.2 RURAL RUNOFF CHART (REVISED)

Example:
Hydrologic Contour 5.0
Drainage Area 35 ac
Small Area – Full Business
Q10=39x1.4=55 cfs




| FREQUENCY FACTORS | | | | |
|---|---|---|---|---|
| Q2 | = | Q10 | x | 0.50 |
| Q5 | = | Q10 | x | 0.75 |
| Q25 | = | Q10 | x | 1.35 |
| Q50 | = | Q10 | x | 1.85 |
| Q100 | = | Q10 | x | 2.15 |
| Q500 | = | Q10 | x | 3.10 |

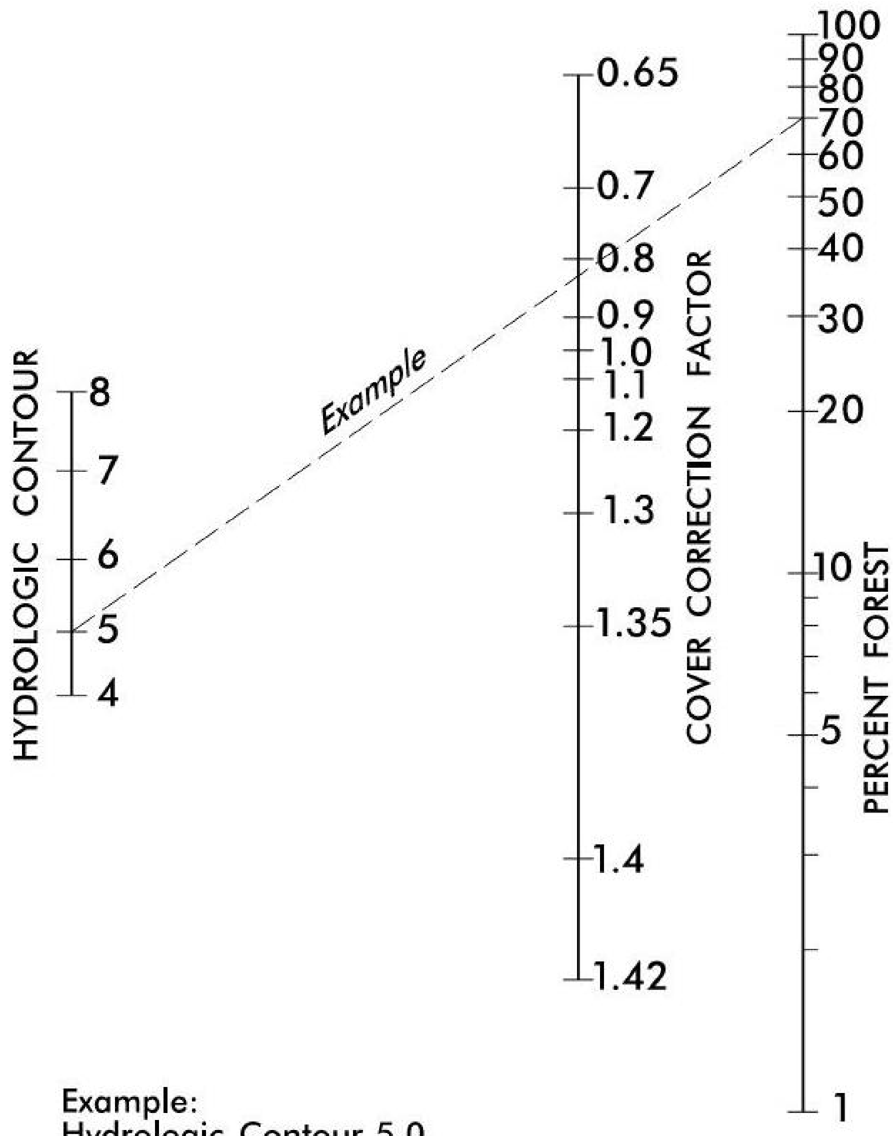
C200.3 URBAN RUNOFF CHART (REVISED)




Example:
Drainage Area 32 ac
W/L=1.2
Q50=25 cfs (from Chart C200.2)
Corrected Q50=25x1.3=33 cfs

DRAINAGE AREA SHAPE PARAMETER
CORRECTION FACTORS

C200.4




Example:
Hydrologic Contour 5.0
Drainage Area 35 ac
70% forest cover
Q50=25 cfs (from C200.2)
Corrected Q50=25x0.84=21 cfs

DRAINAGE AREA COVER PARAMETER
CORRECTION FACTORS

C200.5